



Sometimes, noise can be good

WHEN I STARTED TO WRITE this column, someone saw the title and asked, "You don't have any kids, do you?" Well, I did have the charge of children at one time in my life, but I think people forget two things in their lives: extreme pleasure and extreme pain. The fact

that we forget is what keeps us going back for more. This column is not about going back to painful experiences, such as a noisy circuit. Rather, it is about the pleasure of tackling those difficult analog-noise problems in the digital domain.

We have all sought the perfect conversion in our mixed-signal circuits, in which the converter produces a repeatable, accurate, digital result every time. We use noise-reduction techniques, such as selecting low-noise devices, choosing a careful layout, and performing analog filtering, to remove undesirable signals. But another way to approach noisy

analog-to-digital-conversion problems is to "design" noise into your signal instead of taking it out. For instance, you can get 12-bit accuracy from a 12-bit converter if you are diligent about applying low-noise strategies to your circuit. Alternatively, you can allow a degree of white noise into the circuit and follow the conversion with a processor or controller digital filter. In this scenario, your circuit can produce 14-, 15-, or even 16-bit accuracy. If noise exists in your circuit, you can achieve better resolution at the output of a digital filter by using oversampling techniques.

For instance, if you use a simple rolling-average digital filter, you can calculate the number of bits (N) that you will add to your conversion resolution with the following formula: $\# \text{oversampled data} = 2^N$. If you want to increase your resolution from 11 to 14 bits, you need to accumulate and average 64 samples. Time is the primary trade-off for this increase in resolution. The rolling-average digital-filter algorithm accumulates several samples to calculate the final result. The accumulation of these samples takes time. FIR (finite-impulse-response) and IIR (infinite-impulse-response) digital filters also suit this task.

If you have time, this option sounds like a simple one. However, consider one more issue before

you embrace this combination of analog with digital systems in your circuit. You must know the complexion of your ADC digital output over time. A histogram plot is an appropriate tool to use when examining your digital code over time. The histogram plot displays the number of occurrences of each code. For example, the plot in **Figure 1** shows 1024 repetitive data samples from a 12-bit ADC (sample rate=20k samples/sec).

If you want to successfully increase your converter's resolution, you need to ensure that the noise from the ADC is gaussian. On a histogram plot, gaussian noise looks similar to a statistically normal distribution around a center code. The data in **Figure 1** does not follow the shape of a normal distribution; it appears to have a bimodal response. In addition, the output mean of this system should be 2236 instead of 2297. A digital filter does not "fix" this data. The noise in this system originates in an LED array. Poor layout and high currents through the array make the noise on the board intolerable.

Using a digital filter at the output of your ADC does not relieve you of the responsibility of knowing what kind of data you are producing. Digital filtering improves the resolution of your analog-to-digital conversion, but only if you are confident that the noise response of your data is gaussian. □

REFERENCE

1. Kester, Walt, *Mixed-Signal and DSP Design Techniques*, Elsevier, December 2002.

Bonnie Baker is the analog/mixed-signal-applications engineering manager for Microchip Technology's microperipherals division. You can reach her at Bonnie.Baker@microchip.com.

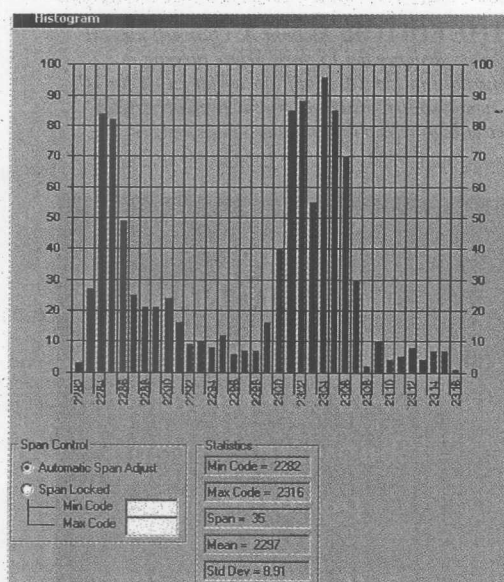


Figure 1 This histogram plot shows bimodal data from an ADC.

It is difficult, if not impossible, to apply digital filtering to this data to recover a digital code that actually and accurately represents the input analog voltage.